Transporte SDH e
Transporte Óptico WDM

SDH, OTN, ASON

ITU-T g.707, g.709, g.8080

2007-2012-2006

(*inicios* 1986-1999-2001)

Transporte Ótico

Histórico

Sistemas digitais de transporte
em Redes Óticas):

-- PDH (inic. 1980; revisoes)
-- Sonet (1984)
-- SDH (1986) [g.707]
-- OTN (2000); (2009-2012) [g.709]
-- ASON (2003); (2006) [g.8080]

Transporte PDH

Anos 1980 até hoje!

PDH

Digital Hierarchy Level	Hierarchical bit rates (kbit/s) for networks with digital hierarchy based on a first level bit rate of	
	1544 kbit/s	2048 kbit/s
- 0 -	64	64
(T1) 1 (E1)	1544 (24,1)	(32) 2048
(T2) 2 (E2)	6312 (98,6)	(132) 8448
(T3a,b) 3 (E3)	32064 / 44736	34368 (537)
4	97728	139264 (2176)

Tamanho do bit $L_b = v_c / B$
[E1=97,3 m]
[E3=5,7 m]
[E4=1,4 m]

evoluem para

SONET → SDH

- escalas *(aprox.)* 4x ;
- canais de voz *exatos* só p/ PDH-SDH;

The frame repetition rate is 8000 Hz (=125µs)

ITU-T Recommendation G.702 -- PDH (1988) ; published as Fascicle III.4 of the *Blue Book* (1993); and ITU-T Recommendation G.704 -- PDH (1998)

Transporte SDH

Hierarquia digital SDH & Sonet

SDH	SONET	Taxa	Canais Voz
Sigla	Sigla	(Mb/s)	(64k)
"STM 0"	OC-1 (STS-1)	51,84	672 (810#)
STM-1	OC-3 (STS-3)	155,52	1920
STM-4	OC-12 (STS-12)	622,08	7680
STM-16	OC-48 (STS-48)	2488,32 (2,5 Gb/s)	30720
STM-64	OC-192 (STS-192)	9953,28 (10 Gb/s)	122880
STM-256	OC-768 (STS-768)	39813,12 (40 Gb/s)	491520

Fator 4 exato

Fator 4 exato

Transporte Ótico

INTERNATIONAL TELECOMMUNICATION UNION ITU-T Recommendation G.707/Y.1322

ITU-T **G.707/Y.1322**
(01/2007)

TELECOMMUNICATION STANDARDIZATION SECTOR OF ITU

SERIES G: TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

Digital terminal equipments – General

SERIES Y: GLOBAL INFORMATION INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS AND NEXT-GENERATION NETWORKS

Internet protocol aspects – Transport

Network node interface for the synchronous digital hierarchy (SDH)

SDH 2007

(*in force*)

Transporte SDH

History

1.0	G.707	1988-11-25
2.0	G.707	1991-04-05
3.0	G.707	1993-03-12
4.0	G.707	1996-03-20
5.0	G.707/Y.1322	2000-10-06
5.1	G.707/Y.1322 (2000) Cor.1	2001-03-15
5.2	G.707/Y.1322 (2000) Cor.2	2001-11-29
5.3	G.707/Y.1322 (2000) Amend.1	2001-11-29
5.4	G.707/Y.1322 (2000) Amend.2	2002-08-06
5.4	G.707/Y.1322 (2000) Cor.3	2003-03-16
5.5	G.707/Y.1322 (2000) Amend.3	2003-04-13
6.0	G.707/Y.1322	2003-12-14
6.1	G.707/Y.1322 (2004) Cor.1	2004-06-13
6.2	G.707/Y.1322 (2004) Amend.1	2004-08-22
6.3	G.707/Y.1322 (2005) Cor.2	2005-08-22
7.0	G.707/Y.1322	2007-01-09
7.1	G.707/Y.1322 (2007) Amend.1	2007-07-29

estudos preliminares sempre iniciam pelo menos 2-3 anos antes

ITU-T Recommendation G.707/Y.1322

Transporte SDH

- Hierarquia digital síncrona, desenvolvida na década de 1980;
- SDH foi desenvolvido desde início para Redes Óticas; criado sobre a base conceitual Sonet (EUA); ambos (SDH/Sonet) evoluiram a partir de PDH;
  - hoje existe uma enorme base instalada (legado) em Telecom & TI, até 40Gb/s, e que inclui múltiplas interfaces com outros formatos e outras hierarquias);
- Historicamente, *25 anos* !!, (1988-2013)
- *=> ao que tudo indica... ainda continuará por muitos anos...*

❑ Definições:

fibra

cliente

- STM-N – *synchronous transport module*; é o quadro (*frame*) que vai efetivamente ser transportado na fibra otica; hierarquia N;
- AUG – *administrative unit group*; hierarquia N ;
- TUG – *tributary unit group*; hierarquia N ;
- VC – *virtual container* ; unidade básica do quadro SDH;
  - *mapeamento* = concatenação digital de mesma hierarquia; (*ver esquema adiante*)
  - *multiplexação* = composição de múltiplos sinais tributários num "envelope" de hierarquia mais alta para transmissão multicanal; (*ver esquema adiante*)

SDH Virtual Containers

=> Vc's que recebem o trafego dos clientes.

Table 6-1 – VC types and capacity

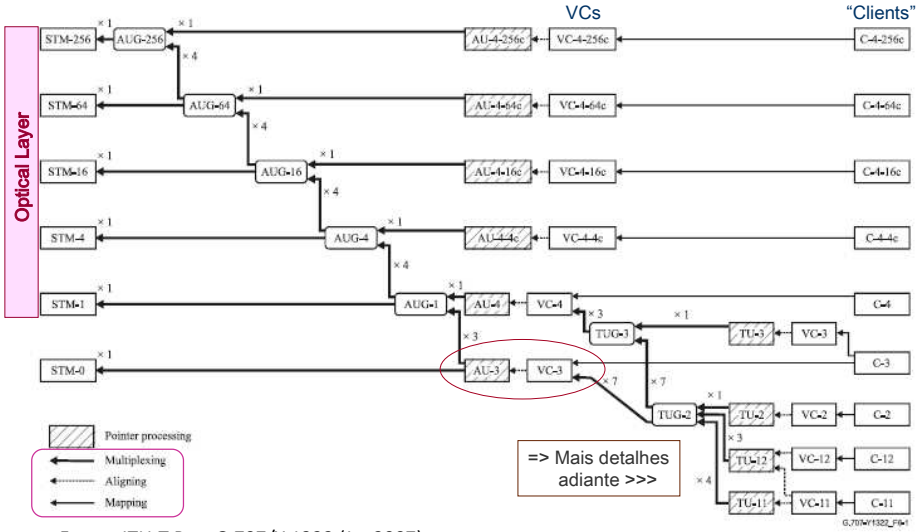
VC type	VC bandwidth	VC payload	
VC-11	1 664 kbit/s	1 600 kbit/s	(T1)
VC-12	2 240 kbit/s	2 176 kbit/s	(E1)
VC-2	6 848 kbit/s	6 784 kbit/s	(T2)
VC-3	48 960 kbit/s	48 384 kbit/s	(T3a,b; E3)
VC-4	150 336 kbit/s	149 760 kbit/s	
VC-4-4c	601 344 kbit/s	599 040 kbit/s	
VC-4-16c	2 405 376 kbit/s	2 396 160 kbit/s	
VC-4-64c	9 621 504 kbit/s	9 584 640 kbit/s	
VC-4-256c	38 486 016 kbit/s	38 338 560 kbit/s	

[sistema] [cliente]

Fonte: ITU-T Rec. G.707/Y.1322 (Jan2007)

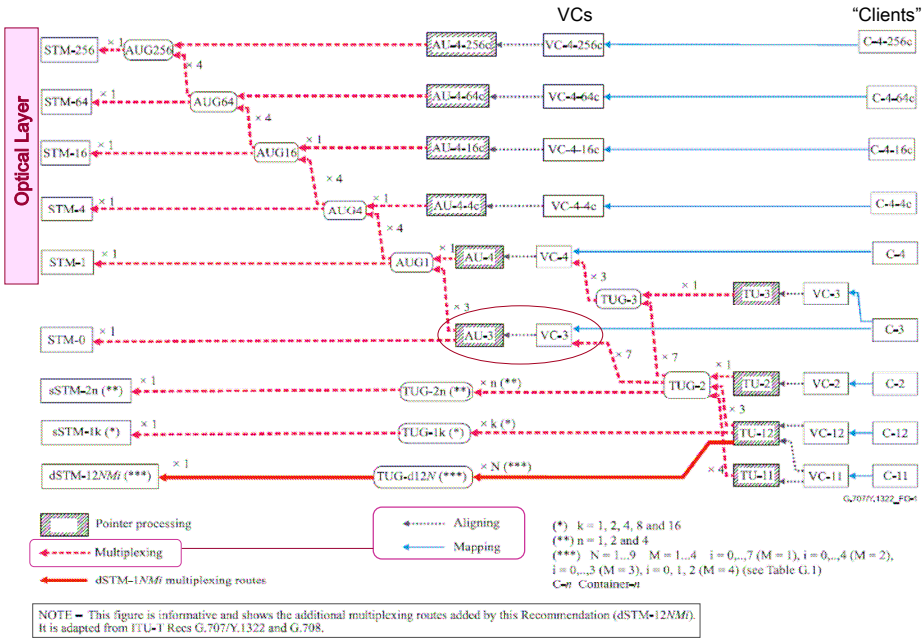
Mux SDH

Demux é similar...
(*só que na ordem inversa*)



Fonte: ITU-T Rec. G.707/Y.1322 (Jan2007)

Figure 6-1 – Multiplexing structure



NOTE – This figure is informative and shows the additional multiplexing routes added by this Recommendation (dSTM-12*NMi*). It is adapted from ITU-T Recs G.707/Y.1322 and G.708.

Figure G.1 – Additional structure for dSTM

Frame SDH

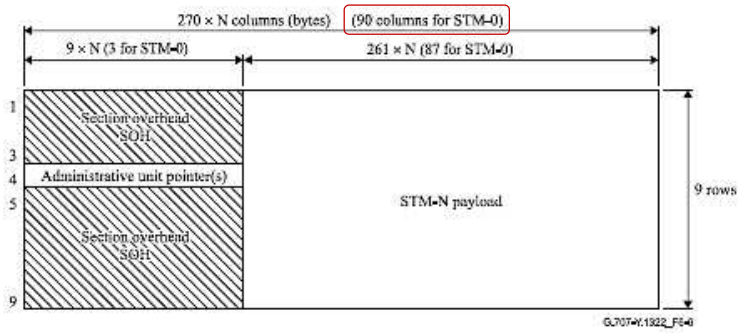


Figure 6-6 – STM-N frame structure

detalhes dos SOH (lines 1-3;5-9) e AUP, veja **ITU-T Rec. G.783 (03/2006)** pg. 34, seç. 10 ; **N = 1, 4, 16, 64, 256**

Fonte: ITU-T Rec. G.707/Y.1322 (Jan2007)

=> compare este frame SDH tamanho variável com OTN tamanho "fixo" [slides 18 e 19]

11

Transporte Ótico

OTN

2001-2003-2009-2012

INTERNATIONAL TELECOMMUNICATION UNION

ITU-T G.872 (11/2001)

TELECOMMUNICATION STANDARDIZATION SECTOR OF ITU

SERIES G: TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

Digital networks – Optical transport networks

Architecture of optical transport networks

Architecture — OTN 2001

Arquitetura não muda !!

ITU-T G.709/Y.1331 (02/2012)

TELECOMMUNICATION STANDARDIZATION SECTOR OF ITU

SERIES G: TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

Digital terminal equipments – General

SERIES Y: GLOBAL INFORMATION INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS AND NEXT-GENERATION NETWORKS

Internet protocol aspects – Transport

Interfaces for the optical transport network

OTN 2012 — Interfaces

- Alterações de 2010 e 2011;
- Nova versão em Fev.2012, = atualiz. (Amend.) Dez. 2012.

12

OTN

2013

Recommend. ITU-T G.870/Y.1352

History -- ***Architecture group***

G.870

Edition Recommendation Approval Study Group

- 1.0 ITU-T G.870/Y.1352 2004-06 SG-15
- 1.1 ITU-T G.870/Y.1352 (2004) Amend.1 2005-06 15
- 2.0 ITU-T G.870/Y.1352 2008-03 15
- 2.1 ITU-T G.870/Y.1352 (2008) Amend.1 2009-11 15
- 3.0 ITU-T G.870/Y.1352 2010-07 SG-15 [supersed.]
- 4.0 ITU-T G.870/Y.1352 **2012**-02 SG-15 (Fev.2012) [released; supersed.]
- 5.0 ITU-T G.870/Y.1352 **2012**-10 (Oct.2012) -- *in force*

=> this *group* is:: g.**870**, Terms & Definitions for Opt.Transp.Netwks.
g.871, Framework of OTN Recommd.
g.**872**, **Architecture** (2001; *in force*)
g.873, OTN Linear Protect & Shared Ring Protect
g.874, Management OTN

Transporte Ótico

INTERNATIONAL TELECOMMUNICATION UNION

Recommend. ITU-T G.709/Y.1331

ITU-T **G.709/Y.1331**
(02/2012)

TELECOMMUNICATION STANDARDIZATION SECTOR OF ITU

SERIES G: TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

Digital terminal equipments – General

SERIES Y: GLOBAL INFORMATION INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS AND NEXT-GENERATION NETWORKS

Internet protocol aspects – Transport

Interfaces for the optical transport network

OTN 2012

(*in force*)

OTN

2013

Interfaces

G.709

History -- *Interfaces*

Edition	Recommendation	Approval	Study Group
• 1.0	ITU-T G.709/Y.1331	2001-02-09	15
• 1.1	ITU-T G.709/Y.1331	(2001) Amd.1 2001-11	15
• 2.0	ITU-T G.709/Y.1331	2003-03-16	15
• 2.1	ITU-T G.709/Y.1331	(2003) Amd.1 2003-12	15
• 2.2	ITU-T G.709/Y.1331	(2003) Cor.1 2006-12	15
• 2.3	ITU-T G.709/Y.1331	(2003) Amd.2 2007-11	15
• 2.4	ITU-T G.709/Y.1331	(2003) Cor.2 2009-01	15
• 2.5	ITU-T G.709/Y.1331	(2003) Amd.3 2009-04	15
• 3.0	ITU-T G.709/Y.1331	2009-12-22	15
• 3.1	ITU-T G.709/Y.1331	(2009) Cor.1 2010-07	15
• 3.2	ITU-T G.709/Y.1331	(2009) Amd.1 2010-07	15
• 3.3	ITU-T G.709/Y.1331	(2009) Amd.2 2011-04	15
• **4.0**	**ITU-T G.709/Y.1331**	**2012-02-13**	15
• 4.1	ITU-T G.709/Y.1331	(2012) Cor. 1 2012-10	15
• 4.2	ITU-T G.709/Y.1331	(2012) Amd. 1 2012-10	15

Transporte Ótico

OTN

G.709/Y.1331

- Definições:
  - OTM (**n**.m) – *optical transport **module***; é o quadro (*frame*) que executa o transporte WDM na fibra otica; os indices ***n*** and ***m*** definem o numero de *wavelengths e bit rates* nas interfaces de entrada e saida;
  - OTU (**k**) -- *optical channel **transport** unit ;* the OTUk is the information structure used for transport of an ODUk over one or more optical channel connections.
    - It consists of the optical channel data unit and OTUk related overhead (FEC and overhead for management of an optical channel connection). It is characterized by its frame structure, bit rate, and bandwidth. OTUk capacities for k = 1, 2, 3 and 4, are defined ;
  - ODU (k) -- *optical channel **data** unit;* the ODUk is an information structure consisting of the information payload (OPUk) and ODUk related overhead;
  - OPU (k) -- *optical channel **payload** unit (OPUk);* the OPUk is the information structure used to adapt client information for transport over an optical channel. It comprises *client information together with any overhead needed* to perform rate adaptation between the *client signal rate and the OPUk payload rate;*
    - **k** -- the index "k" is used to represent a supported bit rate and the different versions of OPUk, ODUk and OTUk.
    - **k = 1** represents an approximate bit rate of 2.5 Gbit/s, **k = 2** represents bit rate of 10 Gbit/s, **k = 3** represents bit rate of 40 Gbit/s, and **k = 4** represents bit rate of 100 Gbit/s; (k=5 is reserved for 400Gb/s systems)

empacotamento

OTM Frame *overheads*

OTN

G.709/Y.1331

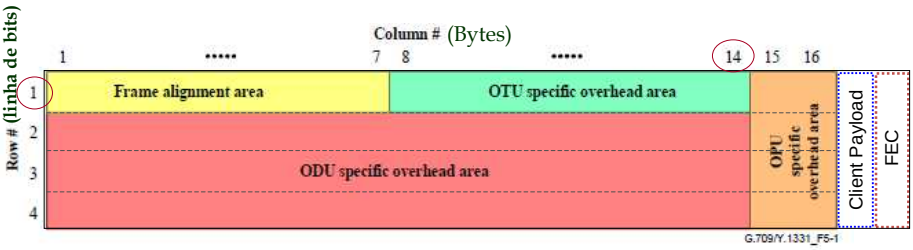


Figure 5-1/G.709/Y.1331 – OTUk, ODUk and OPUk overhead

Order of Assembly: OTM ⇦ OTU ⇦ ODU ⇦ OPU ⇦ [client payload] then: FEC

☞ The order of transmission of information in all the diagrams in this Recommendation is first from left to right and then from top to bottom. The most significant bit (bit 1) is transmitted first. (column numbers are bytes; rows are bits)

OTM Frame construction

OTN

G.709/Y.1331

Optical channel data unit (ODUk)

ODUk frame structure

The ODUk (k = 0,1,2,2e,3,4,flex) frame structure is shown in Figure 12-1. It is organized in an octet-based block frame structure with four rows and 3824 columns.

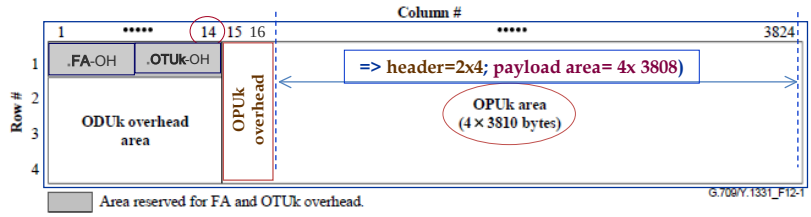


Figure 12-1 – ODUk frame structure

The two main areas of the ODUk frame are:

- ODUk overhead area;
- OPUk area.

Columns 1 to 14 of the ODUk are dedicated to ODUk overhead area.

mais detaljhes pg. 44 **OTN** (2012) [veja Fig. **15.3**]

OTM Frame construction

OTN

G.709/Y.1331

OTUk frame structure

The OTUk (k = 1,2,3,4) frame structure is based on the ODUk frame structure and extends it with a forward error correction (FEC) as shown in Figure 11-1. 256 columns are added to the ODUk frame for the FEC and the reserved overhead bytes in row 1, columns 8 to 14 of the ODUk overhead are used for OTUk specific overhead, resulting in an octet-based block frame structure with four rows and 4080 columns. The MSB in each octet is bit 1, the LSB is bit 8.

NOTE – This Recommendation does not specify an OTUk frame structure for k=0, k=2e or k=flex.

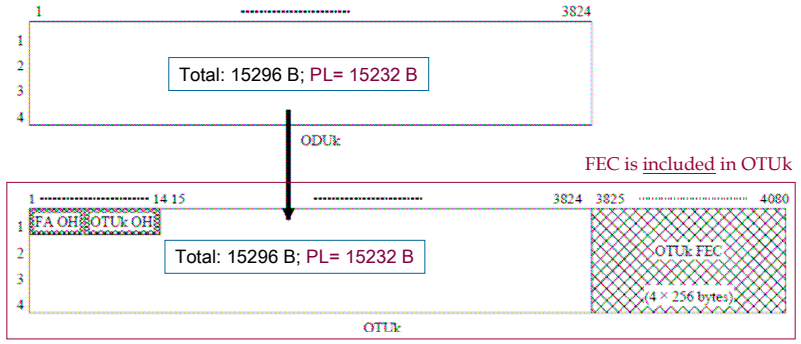


Figure 11-1 – OTUk frame structure

OTM Frame construction

OTN

G.709/Y.1331

- The OTU-k frame is 4080 columns, because it includes the FEC bytes (256 columns) and ODU-k frame (3824 columns); *included* are the overheads (Fig.5-1) ::
  - Frame Aligment area (Line1, B=1-7); then, **OTU** overhead (Line1, B=8-14; 7bytes) ; and **ODU** overhead (Line2-4, B=1-14; 42 bytes); then the **OPU** overhead (Line1-4, B=1-14; 28 bytes) ; OPU *payload* is *fixed* 3808 columns x 04 lines (= 15232 bytes;!);
- Thus, **OTN** has ***fixed*** OTM frame for all bit-rates; only the transmission *speed* (bit-rate) changes with *k*=1,2,3,4 (2,5; 10; 40; 100); by contrast, SDH has ***variable*** STM frame (number of bytes) according to hierarchy N, and also *variable* transmission speed ;
- *Em outras palavras*,
  - um frame STM-64 (10 Gb/s; 155.520 bytes); requer 11 frames ODU-2 (k=2; PL=15232), (porque 10 = 152.320, não dá); resultando, 11 OTM-2 pra ser transportado;
  - um frame STM-256 (40 Gb/s; 622.080 bytes); requer 41 frames ODU-3 (= 624.512 B; ou seja, 41 OTM-3) pra ser transportado;

☞ Importante notar:

1) prevalece o valor de ***k*** (ou seja, a taxa de bit);

2) passando de STM-64 para 256 vale o fator 4x, exato; para transporte OTN isso não vale:: o numero de *containers* OTM-2 para OTM-3 não é exato 4x,

=> *mudança de paradigma* com a evolução das tecnologias. (Fim-OTN) >>

Transporte Ótico

☞ o passo atrás passou a frente...
... e agora foi "re-passado" ...

INTERNATIONAL TELECOMMUNICATION UNION

ASON
2006

ITU-T **G.8080/Y.1304**
(06/2006)

TELECOMMUNICATION STANDARDIZATION SECTOR OF ITU

SERIES G: TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

Ethernet over Transport aspects – General aspects

SERIES Y: GLOBAL INFORMATION INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS AND NEXT-GENERATION NETWORKS

Internet protocol aspects – Transport

Architecture for the automatically switched optical network (ASON)

ITU-T Recommendation G.8080/Y.1304

Transporte Ótico

☞ o passo atrás tinha passado a frente... e agora foi "re-passado", mas continua "vivo"!

- ***Automatically Switched Optical Network*** **(ASON)** is an "intelligent" optical network that can automatically manage the signalling and routing through the network.
- Traditionally, it was necessary to configure separately each cross-connection in the Network Elements - NE (such as an optical switch) to create a new traffic path for a customer.
- In an ASON, this whole process is automated. The customer request defines a new path by its start and end point, the bandwidth needed, the Quality of Service and so on.
- The NEs have the necessary processing functions built in to configure the new traffic path; the ASON creates a light path through the network for this customer. This traffic path can be changed according to the network state and availability; but not while the customer is active. The great advantage of ASON is that is improves network throughput and efficiency without requiring extra equipment to be installed.
  - Switching technologies used in ASON range from simple fiber switching to wavelength (λ) switching to optical packet switching. The components required for the switching are optical cross connects (OXCs), wavelength converters, wavelength selective switches (WSS), and optical add/drop multiplexers (OADMs).
- ASON uses the Generalized MPLS (GMPLS) signalling protocol to set up and monitor edge-to-edge transport connections. ASON concentrates on the optical backbone network. The related ASTN (Automatically Switched Transport Network) is used in the access networks and metropolian area networks.

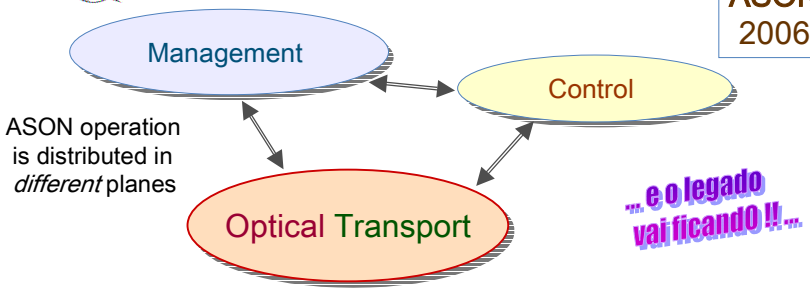
Fonte: Startegies Unlimited, 2012

Transporte Ótico

☞ ...agora (>2011) ASON foi "repassada" por OTN, mas...

INTERNATIONAL TELECOMMUNICATION UNION

ASON 2006



ASON operation is distributed in *different* planes

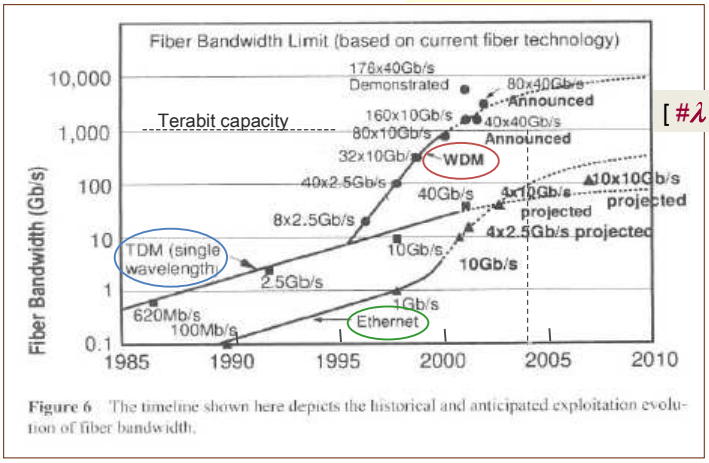
... e o legado vai ficando !! ...

= A grande vantagem funcional da ASON é a separaçao dos planos de Gerencia, Controle, e Transporte Ótico, permitindo que diferentes tecnologias sejam utilizadas (interfaces padronizadas), incluindo GMPLS;
= Outra vantagem é ser compativel com OBS (optical burst switching) que veremos mais adiante.

Fonte: ITU-T Recommendation G.8080/Y.1304 (ASON)

Optical Systems

Evolution



[#λ x Gb/s]

Figure 6 The timeline shown here depicts the historical and anticipated exploitation evolution of fiber bandwidth.

Fonte: R. Singh, D. Harame, Modest Oprysko, *Silicon Germanium – Technology, Modeling, and Design*, **IBM** Technology, IEEE Press/ John Wiley, New Jersey, USA **2004.**